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ABSTRACT

The current period in mathematics education can be characterized as one of reform. Many feel that children in the United States are not learning enough appropriate mathematics; these critics are concerned with the specific areas of problem solving and children's conceptions of the nature and uses of mathematics. A pretest/posttest experimental design study examined the effects of SQUARE ONE TV (SQ1TV), a television series about mathematics aimed at 8- to 12-year-old children, on the problem-solving behavior and attitudes toward mathematics of 240 fifth graders from 4 public schools in Corpus Christi, Texas. Performance and attitude data were collected from a subgroup of 24 students exposed to 30 SQ1TV programs and from 24 students in a control gropu having no SQ1TV contact. Reported here is the Executive Summary, presented in the fifth of a five volume report. After an overview of the entire study, results regarding problem solving, attitudes toward mathematics and problem solving, and viewers' reactions to SQ1TV are described. Significant differences between the two groups indicated viewers showed greater improvement than nonviewers in their use of problem-solving actions and heuristics, in the solutions they reached, and in a number of aspects of attitude. The SQ1TV interview demonstrated that children perceived the series as both fun and about mathematics, and that they were actively doing mathematics as a result of watching the series. (MDH)

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Children's Problem-Solving Behavior and Their Attitudes toward Mathematics
A Study of the Effects of SQUARE ONE TV

VOLUME V

Executive Summary

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Children's Television Workshop
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PURPOSE AND METHODOLOGY OF THE STUDY

The current period in mathematics education can be characterized as one of reform. There is widespread dissatisfaction among professionals and laypeople alike with the present state of mathematics learning in the United States; indeed, much of the literature refers to the current deficiencies as a "crisis" in mathematics education. Proponents of reform argue that children need to become mathematical problem solvers and to develop more positive attitudes toward mathematics.

SQUARE ONE TV was designed in an attempt to contribute to this reform effort. The series has three educational goals:

I. To promote positive attitudes toward, and enthusiasm for, mathematics;

II. To promote the use and application of problem-solving processes; and

III. To present sound mathematical content in an interesting, accessible, and meaningful manner.

The aim of the present study is to examine the extent to which **SQUARE ONE TV** has met its first two goals, that is, the extent to which it has a positive impact on children's problem-solving behavior and their attitudes toward mathematics.

Fifth graders in four public elementary schools in Corpus Christi, TX, participated in the study. This site was selected because **SQUARE ONE TV** had not been part of the local after-school broadcast schedule prior to the completion of data collection, and it had not been shown in school. Each of the schools provides a standard, district-wide mathematics program using a popular mathematics textbook.

Over an eight-week period, the children in two of the schools (the "viewer" group) were shown 30 episodes of **SQUARE ONE TV** while the children in the other schools (the "nonviewer" group) were not. Although these episodes were shown in school, teachers did not

incorporate them into their lessons and did not comment upon them in any way; thus, the children's exposure to the series consisted of sustained, unaided viewing.

Forty-eight children (24 from each group), matched for sex, socioeconomic status (SES), ethnicity, and performance on a standardized mathematics test, were tested before and after the eight-week viewing period in an experimental pretest/posttest design. One half of the children were boys and one half were girls; 67% were Latino, 4% were African-American, and 29% were Anglo; these percentages mirrored those of the school system as a whole.

Problem solving was tested via several hands-on, nonroutine mathematical Problem-Solving Activities (PSAs), each of which could be solved through a number of approaches. The three PSAs represented a range of complexity. The least complex problems (PSAs A and A') were combinatorics problems involving orders of stripes on a shirt or of circus performers. PSAs B and B' (which were of medium complexity) asked children to sort cards representing party guests or price tags into groups meeting several conditions. PSAs C and C', the most complex problems, presented children with a mathematical game and asked them to figure out what was wrong with the game and how to fix it. Children received one set of PSAs (either A, B, and C or A', B', and C') at the pretest and the other set at the posttest. (For the purposes of this document, we refer to the pair of PSAs A and A', for example, as PSA A*.)

Attitudes were assessed through an Attitude Interview that employed open-ended questions and extensive probing of the children's responses to produce a portrait of the children's attitudes. The Attitude Interview focused on four dimensions of attitude: children's constructs of mathematics (i.e., conceptions of what mathematics and problem solving are), their perceptions of its usefulness and importance, their enjoyment of the subject, and their motivation. Questions were asked within three domains of inquiry: the Mathematics Domain (focusing on what the children identified as "math" and their relationship to it), the Figuring Out Domain (i.e., problem solving in general), and the PSA Domain (in which questions about

problem solving were discussed in the context of a concrete example of problem solving, that is, the PSAs).

Both at the pretest and at the posttest, each child was tested individually in two 55-minute sessions, the first consisting of two PSAs and the second containing the third PSA, embedded in the approximately 40-minute Attitude Interview. The CTW interviewers and coders were blind to the children's viewer/nonviewer status; that is, they did not know which children were viewers and which were not. Similarly, the children did not know of the interviewers' connection to **SQUARE ONE TV**.

In addition, some aspects of the attitudes of all of the 240 fifth graders in the four schools were assessed via a large-group, written measure, the Essay. This measure was administered near the end of the treatment period. The children's teachers presented them with what was apparently a typical in-class writing assignment: they were asked to write essays about why they would or would not want to have a job connected to mathematics. The children's responses to the Essay were analyzed for two of the attitude dimensions listed above: construct of mathematics and usefulness/importance.

After all of the above testing was concluded, an additional, 30-minute interview asked viewers for their specific evaluations of and reactions to **SQUARE ONE TV**.

For further detail on the purpose, sample, and design of the study, we refer the reader to Volume I of this report.

RESULTS

This section presents a short description of our results regarding problem solving, attitudes toward mathematics and problem solving, and viewers' reactions to **SQUARE ONE TV**. Please note that this data arose from approximately four hours of interviews per child. The interviews produced a rich, detailed data set that is only summarized briefly here. The reader is referred to Volumes II, III, and IV to gain a deeper understanding of the study's findings.

Problem Solving

For each of the three PSAs, each child was scored on two measures: (1) the number and variety of problem-solving actions and heuristics used (the Problem-Solving Score, or P-score) and (2) the mathematical completeness and sophistication of the solution reached (the Mathematics score, or M-score). The results of this investigation of problem solving are presented in detail in Volume II of the full report of the study. The principal findings, briefly stated, are as follows:

o Viewers showed statistically significant[1] gains in the number and variety of problem-solving actions and heuristics they used to solve problems (e.g., looking for patterns, transforming problems); at the posttest, viewers used a significantly greater number and variety than nonviewers. Moreover, at the posttest, viewers used a greater proportion of new actions and heuristics (i.e., ones that they had not used in the pretest) than nonviewers did; this difference was significant for two of the three PSAs and marginal for the remaining one.

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[1] We have set our α level for significance at .05; any results referred to as significant achieved at least that level of significance. Results with p values between .05 and .10 are referred to as marginal.

o Similarly, viewers showed significant gains in the mathematical completeness and sophistication of the solutions that they reached. That is, their solutions to two of the three PSAs became significantly more complete and sophisticated after watching the 30 episodes of **SQUARE ONE TV**, while nonviewers showed no significant change.

o All of the above results occurred regardless of the children's sex, ethnicity, or SES. The series exerted a similar effect on boys and girls of different backgrounds.

o Ten months before the study began, the local school district administered a standardized mathematics achievement test to all of the children in the participating schools. Neither the children's P-scores nor their M-scores were significantly related to their performance on the test. Similarly, the pretest-posttest gains shown by viewers did not vary as a function of the children's performance on the standardized test.

o Further analyses of the children's performance suggested that, while **SQUARE ONE TV** had direct effects on both P-scores and M-scores, its effect on the children's M-scores was also, in part, mediated by its effect on P-scores. That is, exposure to the series resulted in the children's using an increased number and variety of problem-solving behaviors, which in turn led them to reach more complete and sophisticated solutions.

Attitudes

The present study of children's attitudes toward mathematics and problem solving consisted of two parts: (1) a descriptive analysis that employed data from the Attitude Interview to provide a detailed examination of the children's attitudes in the absence of any treatment (i.e., in the pretest), and (2) an analysis of change that used data from both the Attitude Interview and the Essay to investigate the effects of **SQUARE ONE TV** on the children's attitudes. The results of the analysis of change are presented here. The reader is

referred to Volume III for the results of the descriptive analysis, as well as a more detailed report of the analysis of change.

Construct of Mathematics

o One analysis focused on children's conceptions of what mathematics is by examining the types of mathematics that the children mentioned as examples of "math." A marginal difference between the two groups was observed over time in that viewers showed significant gains in the degree to which they spoke about areas of mathematics beyond basic arithmetic. At the posttest, viewers spoke about these areas of mathematics significantly more than nonviewers did. These effects occurred regardless of the children's sex, ethnicity, or SES; boys and girls of all backgrounds were affected similarly.

o A second analysis examined children's conceptions of problem solving. Viewers showed significant gains in the degree to which they discussed practical and sophisticated problem solving (rather than talking about basic computation or simply mentioning "problem solving" or "figuring out" without further elaboration), while nonviewers did not. These effects occurred regardless of the children's sex, ethnicity, or SES.

o The content areas of mathematics listed in Goal III of **SQUARE ONE TV** were used to classify the areas of mathematics that the children recognized as mathematics, both in the Attitude Interview and in the Essay. In the Attitude Interview, viewers made marginally more mentions of Geometry than nonviewers did at the posttest. In the Essay, significantly more viewers than nonviewers mentioned examples of Measurement, and marginally more viewers than nonviewers mentioned examples of Geometry.

Usefulness and Importance

o Our analysis of data from the Attitude Interview focused on the number of applications of mathematics that the children discussed, the types of applications they

described (i.e., whether given applications were bound to the context established in the interview question or created entirely by the children), and time of the applications (i.e., whether applications pertained to the present or the future). There were no significant effects of **SQUARE ONE TV** on any of these three measures.

o However, data from the Essay revealed that marginally more viewers than nonviewers wrote about specific applications of mathematics (e.g., an architect's using measurement). This finding did not differ for boys and girls of different SES or ethnic backgrounds. Viewers and nonviewers did not differ significantly in the degree to which they wrote about specific areas of mathematics (as opposed to producing more general discussions of "math").

Motivation

o One analysis focused on children's orientation toward motivations, that is, the nature of their reasons for being motivated-- or not being motivated-- toward mathematics and problem solving. Viewers made significantly greater gains than nonviewers in the degree to which their motivation was focused on engagement with the process of mathematics and problem solving (rather than a concern with getting the "right answer" or rewards for being right). This effect did not depend on the children's sex or ethnicity, but the effect was strongest for viewers of lower socioeconomic backgrounds.

o Our notion of orientation is similar to a distinction that previous researchers have drawn between children whose motivation is related to a learning goal (in which motivation stems from an interest in mastery and acquiring knowledge or skills) versus a performance goal (which focuses on obtaining favorable judgments of one's competence). In the posttest, we employed the same measure used previously in the literature to assess the motivational goals held by viewers and nonviewers. Significantly more viewers than nonviewers indicated that they held a learning goal, a result similar to the one we observed for orientation. This effect did not differ as a function of the children's sex, ethnicity, or SES.

o A marginal difference between viewers and nonviewers was observed with regard to the degree to which they were motivated to pursue or avoid the mathematical activities discussed in the course of the Attitude Interview (which we refer to as "valence"). Both viewers and nonviewers tended to want to pursue such activities in the pretest. However, while nonviewers were significantly less likely to want to pursue such activities in the posttest, viewers maintained the same level of motivation as they had shown previously. These effects did not vary as a function of the children's sex, SES, or ethnicity.

o A further analysis, which we call magnitude, combined valence with the sophistication of the children's reasons for their motivation. We observed no effect of **SQUARE ONE TV** on this variable.

o A series of eight analyses was performed to assess children's inclination to pursue sophisticated problem-solving tasks. Each analysis involved forced-choice questions about the tasks that the children would most like to pursue: which of the three PSAs they would want to try again, and whether they would prefer to work on another problem like PSA C* (the most complex PSA) or an arithmetic worksheet containing division problems.

Six of the eight analyses showed that after exposure to 30 episodes of **SQUARE ONE TV**, viewers were significantly more likely than nonviewers to want to pursue the tasks that were objectively the most complex and difficult and that they (subjectively) considered to be the most challenging. Over the eight analyses, no consistent differences were found to result from the children's sex, ethnicity, or SES.

Enjoyment

Two types of analyses were used to examine children's discussions of their enjoyment of mathematics and problem solving in the Attitude Interview. One type consisted of several analyses focusing on their responses to questions that asked directly about enjoyment. The

second type concerned their spontaneous mentions of enjoyment throughout the remainder of the interview.

o Several analyses of children's responses to questions about enjoyment focused on their orientation toward enjoyment (i.e., the nature of their reasons for enjoying -- or not enjoying -- mathematics and problem solving). Three analyses were used: one examining children's responses as a whole, one focusing specifically on their discussions of mathematics, and one examining their responses about problem solving (as reflected in the PSAs). Analyses of the children's responses to the enjoyment questions as a whole and to questions asking specifically about mathematics revealed no significant differences between viewers and nonviewers.

However, an analysis of their responses to questions about their enjoyment of problem solving (as reflected in the PSAs) revealed a marginal difference between the two groups in the degree to which their enjoyment was derived from thinking, that is, their intellectual involvement with problem-solving tasks. When the variance accounted for by the children's sex or ethnicity was controlled for statistically, this difference became significant. Nonviewers declined significantly in the degree to which they spoke about enjoyment in this way, and in the posttest, viewers spoke about deriving enjoyment from thinking to a significantly greater degree than nonviewers did. Male and female viewers produced these statements to a similar extent, and no differences were found as a function of the children's SES or ethnicity.

o As in our analysis of motivation, children's statements about enjoyment were analyzed according to whether they indicated positive or negative feelings toward mathematics (i.e., valence) and magnitude (which combined valence with the sophistication of the children's reasons for enjoyment). Neither analysis revealed significant differences between viewers and nonviewers.

o However, viewers showed significantly greater gains than nonviewers in the number of times they spontaneously talked about enjoying mathematics and problem solving throughout the interview (i.e., without being asked directly about enjoyment). Because these statements

about enjoyment were unsolicited, this result is particularly gratifying. Again, this effect did not vary as a function of the children's sex, ethnicity, or SES.

Viewers' Reactions to SQUARE ONE TV

Viewers' reactions to and evaluations of **SQUARE ONE TV** are presented in Volume IV of the full report. Some of the results, briefly, are these:

o When asked open-ended questions about their evaluations of **SQUARE ONE TV**, almost all of the viewers said that it was funny and fun to watch. Many also spoke about the show's educational or mathematical focus. Thus, these children clearly associated the series with both mathematics and fun.

Throughout the interviews, several other themes emerged among the viewers' discussions of **SQUARE ONE TV**:

o Eighteen of the 24 viewers enjoyed **SQUARE ONE TV** because of its humor (including its dialogue, jokes, and parodies). Approximately one half of the viewers spoke about its entertainment value (including the mathematical magic tricks shown).

o Almost all of the viewers said they learned something from watching **SQUARE ONE TV** or that it reinforced material that they had learned in school. Two thirds of the viewers gave specific examples of things that they learned from the series, including common denominators, geometric shapes, and calculations with decimals. Also, almost one half of the viewers said that **SQUARE ONE TV** teaches that mathematics (in the words of one child) "can be fun too...Some people, they just think, 'Oh, math, it's just -- just there for us to learn, not

nothing fun.' But it's like they way they [SQUARE ONE TV] put it, it seems fun...You can play games with it and you can learn from it too."

o Most viewers spoke about the problem solving shown on **SQUARE ONE TV** as containing multiple problems and identified ways in which problems were formulated, treated, and solved on the series. The problem solving on **SQUARE ONE TV** was seen as an active process of thinking and reflection, not as a rote or formulaic procedure.

o While the viewers thought of mathematics primarily in terms of basic arithmetic (which the research literature suggests is typical), numerous viewers also spoke about examples of other types of mathematics (e.g., geometry) that they had seen on **SQUARE ONE TV**.

o Of the 24 viewers, 22 said that they had participated during or after viewing -- for example, by playing along with the game shows, by telling Mathman (an animated, "Pac-Man"-like character) whether or not to eat certain numbers, or by talking about the material shown on **SQUARE ONE TV** with their families or friends after viewing.

o All of the viewers spoke about ways in which they had seen mathematics applied in **SQUARE ONE TV**, particularly in "Mathnet" (an ongoing mystery serial that parodies "Dragnet"). Approximately three quarters of the viewers also spoke about ways in which they could apply the mathematics from **SQUARE ONE TV** in their own lives.

o Across all of these themes, there were no substantive differences among the viewers' reactions as a function of their sex or SES. The reactions described above came from both boys and girls and from children of different socioeconomic backgrounds.

CONCLUSION

The results described above are highly positive. Despite the fact that the viewers' exposure to **SQUARE ONE TV** took place without any further curricular enhancement, significant differences between the two groups appeared after the viewers watched 30 programs of the series. Viewers showed a significantly greater improvement than nonviewers in their use of problem-solving actions and heuristics, in the solutions they reached, and in a number of aspects of attitude. In addition, the **SQUARE ONE TV** Interview demonstrated that children perceived the series as both fun and about mathematics, and revealed that the viewers often participated both during and after viewing; thus, these children were not only viewing mathematics on **SQUARE ONE TV** but also actively doing mathematics as a result of watching the series.

These results are very encouraging for the reform movement in mathematics education for a number of reasons. First, they provide a clear indication that material produced in response to the goals of the reform movement can have the desired impact on children's problem solving and several aspects of their attitudes. Second, they illustrate the types of measures that can be used to assess children's performance on nonroutine problem-solving tasks and their attitudes toward mathematics and problem solving. Finally, they demonstrate that **SQUARE ONE TV** can play a significant role in the effort toward reform.